Prioritized Technology: System Autonomy – Autonomous Navigation for EDL

Technical Goal

Localization and hazard detection for EDL within 100m of point targets

- Safeguarding: Detect hazardous surface features (crevasses, fractured terrain, jagged penitente fields, etc)
- Targeting: Select final landing site during descent or low-altitude fly-over by incorporating science sensors as part of EDL process

Major challenges:

- Terrain relative localization (TRN) in dark/shadowed regions, over uniform surfaces (liquid, ice, etc), and in areas of extreme vertical relief/roughness
- Active science sensing during landing to inform landing site selection
- Detecting non-geometric surface hazards

Technology advances are required in:

- Real-time mapping and feature matching algorithms appropriate for descent and landing trajectories
- On-board landing site targeting (terrain classification, site characterization, etc) based on science potential, not just geometry
- Hazard detection in dynamic or poor lighting conditions

Mission Applications

- Enable spacecraft to autonomously plan and execute landings that consider not only mission safety, but also science objectives
- Enable spacecraft to land at locations that cannot be extensively mapped prior to entry (descent through clouds, landing in poorly lit regions, etc) and with more challenging landing hazard distributions than is currently possible
- Significantly enhance the scientific return of lander missions: increases likelihood to land at a target of interest (reduce landing ellipse in order to pinpoint targets within a few meters of interest, such as such as young lava flows, Maat Mons volcano, and interiors of craters.)
- Autonomous navigation serves several mission architectures that benefit from sampling high-return areas (lander only, hopping landers, lander with daughter-craft)
- Enables landing in regions currently considered to be too uncertain, risky, or difficult to access
- Enable missions to icy moons and ocean worlds

Technical Status

- Traditional EDL relies on sensors that are used to measure relative range (separation distance) and to characterize terrain geometry (height, roughness, etc) without explicit estimation or representation of other characteristics (trafficability, science value, etc)
- Current EDL does not consider non-geometric information about biomarkers, materials, features, etc. that can point to areas of potentially high science return (i.e., science targets visible during EDL)
- Terrain-relative velocity estimation has been flow with radar and imaging sensors.
- Terrain-relative position estimation for precision landing (using image to map matching) on Mars and the Moon is under development, but has not yet flown and is not generalized for other bodies.
- COLDTech ICICLES project is developing perception, navigation, and planning algorithms for intelligent landing on ocean worlds/icy moons to TRL 5. STMD SPLICE project is has demonstrated suborbital flights.
- Venus may be the hardest place in the solar system to do guided descent, due to the optically dense atmosphere and very high temperatures below ~ 50 km altitude. GNC for Venus has had very little study; some plausible approaches exist, but maturity is TRL 1-2.

Development Cost and Schedule